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(71) Applicant (*for all designated States except US*): **CUDD PRESSURE CONTROL, INC.** [US/US]; 8032 Main Street, Houma, LA 70360 (US).

(71) Applicants and
(72) Inventors: **FERGUSON, Andrew, M.** [US/US]; 1333 S.W. 121st Place, Oklahoma City, OK 73170 (US). **MCKINLEY, Bryan, F.** [US/US]; 10020 Brookmill Court, Oklahoma City, OK 73159 (US). **BRITTON, Mark, S.** [US/US]; P.O. Box 298, Carter, OK 73627 (US). **OVERSTREET, Charles, C.** [US/US]; 7979 Westheimer #1216, Houston, TX 77063 (US).

(74) Agent: **LEE, Mary, M.**; 3441 W. Memorial Road, No. 8, Oklahoma City, OK 73134 (US).

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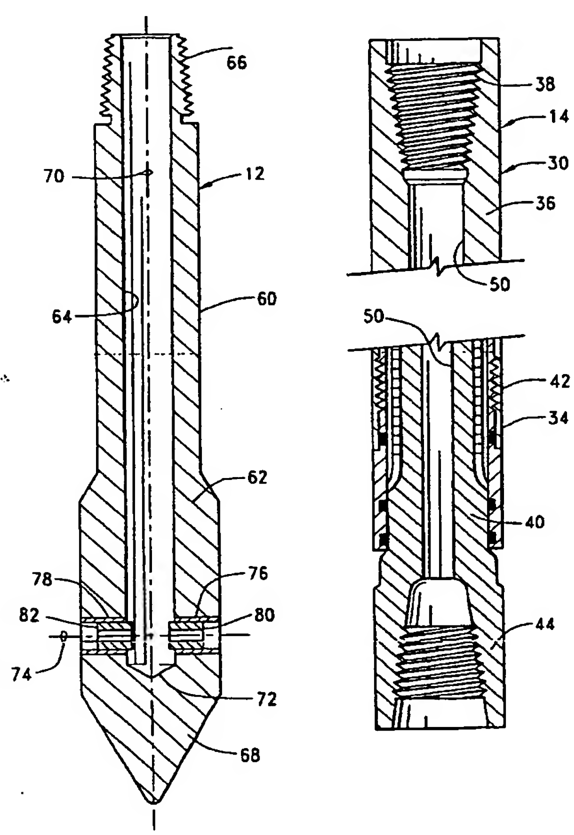
(54) Title: CUTTING TOOL AND METHOD FOR CUTTING TUBULAR MEMBER



(57) Abstract: A fluid cutting tool and method for perforating or severing tubular members from inside. The tool is especially suited for use with a rotational drive system, such as a downhole motor, to separate downhole structures, such as stuck production tubing. The cutting tool preferably takes the form of an elongate metal body with an open first end connectable to the end of a downhole motor. The downhole end of the tool may be conical. A fluid conduit within the body of the tool communicates with the fluid channel in the downhole motor. Ports in the sides of the tool body direct jets of cutting fluid out the side of the tool. The tool attached to the motor is fed downhole until the tool is at the desired location in the well. Then the motor is operated to rotate the tool while cutting fluid is pumped through it. This causes the jets of fluid to be directed at the inner surface of the production tubing (or other tubular structure). This process is continued until the tubing is perforated or severed, as needed.

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CUTTING TOOL AND METHOD FOR CUTTING TUBULAR MEMBER

TECHNICAL FIELD

The present invention relates generally to cutting tools and, more particularly, to cutting tools that employ fluid as the cutting element.

BACKGROUND OF THE INVENTION

In the oil and gas industry, it is often necessary to cut, perforate or separate tubular members downhole. For example, when a drill pipe becomes stuck, the drill string must be severed above the stuck point so that the upper portion can be removed. It is sometimes desirable to sever casing or tubing downhole to make repairs or withdraw the tubing from a well that is being abandoned. Occasionally, the tubing or casing may need to be perforated downhole to improve recovery from a formation. Various cutting devices have been used for these purposes. Chemical cutters may be used, but have temperature and pressure limitations. Mechanical cutters may be used, but have size and strength limitations.

SUMMARY OF THE INVENTION

The present invention is directed to a cutting tool. The tool comprises a body formed by a wall and having a longitudinal axis and a fluid conduit. At least one port is formed in the body in fluid communication with the fluid conduit, so that the port is positioned to direct fluid from the fluid conduit through the wall of the body at an angle to the longitudinal axis.

The present invention further comprises a cutting tool assembly. The assembly includes a cutting tool comprising a body formed by a wall and having a first end and a second end. The body has a longitudinal axis and comprises a fluid conduit. At least one port is formed in the body in fluid communication with the fluid conduit, so that the port is positioned to direct fluid from the fluid conduit through the wall of the body at an angle to the longitudinal axis of the body. The assembly further includes a rotational drive system with a first end and a second end. The first end is connectable to a drive source, and the second end is connectable to the first end of the cutting tool.

Still further, the present invention includes a method of cutting a tubular member having a lumen defined by a sidewall with an inner surface. The method comprises directing a jet of fluid from within the lumen of the tubular member at the inner surface of the sidewall in a circumferential motion until the sidewall is at least partially cut.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 shows a longitudinal, sectional view of a fluid cutting tool assembly of the present invention positioned inside the production tubing in an oil well at a selected cutting location.

Figure 2 shows an enlarged, fragmented sectional view of a preferred cutting tool assembly comprising a fluid cutting tool attached to the downhole end of downhole motor.

Figure 3 shows an enlarged side elevational view of the cutting tool inside a tubular member.

Figure 4 shows a transverse sectional view taken along line 4-4 of Figure 3.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

The present invention is directed to a fluid cutting tool and method particularly suitable for downhole cutting operations. This fluid cutting tool will operate at a wide range of temperatures and pressures. It can be driven by different types of drive systems commonly available at the well site, including downhole motors, threaded pipes and coiled tubing. The fluid cutting tool and method of this invention can be used to cut tubular members having a range of internal diameters. The tool itself is simple to manufacture from a solid steel rod. In addition, it has no moving parts and, thus, is durable and requires minimal repair and maintenance. These and other advantages will become apparent from the following description.

With reference now to the drawings in general and to Figure 1 in particular, there is shown therein a cutting tool assembly in accordance with present invention and designated generally by the reference numeral 10. The assembly 10 generally comprises a cutting tool 12 and a downhole motor 14 drivingly supported by a drill string 16. In this view, the assembly 10 is shown positioned downhole inside a production tubing 18 within a well casing 20. The casing 20 is shown extending into the earth 22 to an underground formation (not shown).

The rotational drive system, such as the motor 14, may vary and is selected depending on the circumstances and available equipment. Suitable rotational drive systems often readily available at a well site include a downhole motor, threaded pipe, and coiled tubing. In the embodiment shown and described herein, a downhole motor 14 will be used as the drive system.

Turning now to Figure 2, the preferred assembly will be described in more detail. As indicated, the cutting tool 12 may be driven by a conventional downhole motor 14. Typically, downhole motors comprise a motor section 30, a connecting section (not shown), and a bearing section 34.

The motor section 30 comprises a torque-creating motor. In most instances, the motor will be a Moineau-type positive displacement pump (not shown). This type of pump typically is composed of an inner elongate rotor supported within an outer tubular section, or stator, having a rubber lining. However, other types of positive displacement pumps and motors may be used. The upper end of the motor section, or top sub 36, is connected by the threaded box end 38 to the drill string 16 (Figure 1) or coiled tubing or threaded pipe or the like.

The connecting section (not shown) usually comprises an inner elongate member, such as a connecting rod, supported in an outer tubular universal housing. The upper end of the connecting rod is drivingly connected to the downhole end of the rotor in the motor section 30, as by a threaded connection.

The bearing section 34 comprises inner elongate member such as a drive shaft 40 supported in an outer tubular member such as the bearing housing 42. The downhole end of the drive shaft 40 preferably extends a distance beyond the downhole end of the bearing housing 42 and may be provided with a threaded box end 44 to connect to the cutting tool 12. The upper end (not shown) of the drive shaft 40 is drivingly connected to the downhole end of the connecting rod, usually by a threaded joint. The upper end (not shown) of the bearing housing 42 is threadedly connected to the downhole end of the universal housing.

In a manner well known in the art, the motor section 30, the connecting section and the bearing section 34 form a continuous fluid pathway 50 for transmitting drilling fluid or "mud" through the motor 14. To provide a fluid seal, the various joints may be provided with O-rings or other seal assemblies. In accordance with the present invention, the downhole motor 14 conveys a cutting fluid under pressure to the cutting tool 12. Thus, the use of motors with sealed bearing sections is recommended.

With continuing reference to Figure 2, the preferred cutting tool 12 will be described. Preferably, the tool 12 comprises a body 60 formed of a wall 62 to define a fluid conduit 64 therein. In most instances, the body 60 will be elongate and generally cylindrical, but other configurations may be used instead, depending on the application.

The tool 12 usually will have a first or upper end 66 and a second or downhole end 68. It is most convenient to provide the upper end 66 with a male threaded or pin end to connect to the female or box end 44 of the downhole motor 14. The tool 12 is characterized as having a longitudinal axis 70.

The downhole or second end 68 of the tool 12 may take various shapes. In most cases a conical end will be preferred. The fluid conduit 64 is open at the upper end 66 to communicate with the fluid pathway 50 in the motor 15. The fluid conduit 64 terminates at a blind end 72 inside the body 60.

The tool 12 may be formed from a solid steel rod by machining the threaded pin end 66, the conical end 68 and fluid conduit 64 inside. The size and dimensions of the tool 12, of course, may vary and, thus, the size of the starting rod stock may likewise vary. A preferred size of tool may be made from 2 7/8 inch, 8.7 pound, P-110 pipe.

Referring still to Figure 2, the tool 12 comprises at least one port as an outlet for the cutting fluid. The number and relative positions of the ports may vary, depending on the circumstances, although they will all communicate with the fluid conduit 64. The ports are positioned to direct cutting fluid from the fluid conduit through the wall 62 of the body 60 at an angle to the longitudinal axis 70 and preferably along the axis 74. In the embodiment shown herein, there are two ports 76 and 78 extending radially from fluid conduit 64 near the blind end 72 at 180 degrees from each other and perpendicular to the longitudinal axis 70.

Because of the abrasive nature of the preferred cutting fluid, it will be advantageous to fix nozzles 80 and 82 in each of the ports 76 and 78. Tungsten carbide nozzles are commercially available in a range of sizes and are well suited for this application. In the embodiment described, 0.106-inch nozzles are preferred.

As indicated, the cutting tool assembly 10 of this invention is designed for use with a cutting fluid. As used herein, "cutting fluid" refers to any liquid or gas composition which can be forced through the drive system and cutting tool and which is capable of having a cutting action on the chosen substrate. The composition of the particular fluid may vary widely depending on the nature of the cutting application. In the preferred practice, the cutting fluid will comprise a liquid and an abrasive agent, such as an abrasive particulate.

When used with a downhole motor, a water-based liquid is suitable. In this application, the fluid preferably comprises a mixture of water and a relatively fine mesh sand as the abrasive agent; 100-mesh sand is ideal. In most instances, it will efficacious to add a gelling or viscosifying agent to the sand and water mixture. One preferred gelling agent is XANVIS brand gelling agent. This cutting fluid may be prepared by placing about 5 barrels of water in a hopper and adding the XANVIS brand gelling agent in the amount of 25 pounds per 10 barrels of water. Then, the 100-mesh sand is added in the amount of about 1 pound of sand for every gallon of water.

With reference now to Figures 3 and 4, the use of the cutting tool 12 will be explained in accordance with the method of the present invention. First, a cutting tool of suitable size is selected. The tool 12 then is attached to the desired rotational drive system, such as a downhole motor 14 (see Figure 2). The cutting tool 12 is positioned at the selected location within the tubular member, such as the production tubing 18 in an oil or gas well (Figure 1).

Once the tool 12 is positioned, at least one and preferably two jets or streams 86 and 88 of cutting fluid are directed from the tool 12 within the lumen 90 (Figure 4) of the tubing 18 toward the inner surface 92 of the tubing 18. Although the volume, pressure and speed of the cutting fluid will vary, in the embodiment described the cutting fluid is pumped through the assembly 10 at about 3000 psi. Given the size of the nozzles and the other parameters, this produces a fluid stream of about 1000 feet per second.

The jets of cutting fluid are directed in a circumferential motion, preferably as illustrated by the arrows 94 in Figure 4. This motion may be oscillating, continuous or pulsed. In the embodiment shown where the assembly utilizes a downhole motor, the tool 12 is continuously rotated at about 200 rpm. The application of the cutting fluid stream to the inner wall 92 of the tubing 18 is continued until the desired perforation or separation of the tubing is achieved. In the embodiment described, the jets of fluid are directed generally perpendicular to the longitudinal axis of the tool and generally normal to the inner surface 92 of the tubing 18. However, the jets may be directed at any angle from the longitudinal axis of the tool.

Now it will be apparent that the cutting tool assembly and method of the present invention offers many advantages. It is easily manufactured of common rod stock. It is sturdy and requires little maintenance. The use of a pressurized cutting fluid

instead of mechanical elements such as bits or blades permits a single tool to be used in tubular members of different internal dimensions. The fluid cutting process also allows the tool to be used to cut elements that are non-circular or irregularly shaped. The fluid will operate at a wide range of temperature and pressure conditions, and is not affected significantly by the direction of the tubular member; it will function horizontally as well as vertically, and in curved or straight tubular sections.

It will be appreciated that the fluid cutting tool and method of the present invention, while particularly suitable for downhole cutting applications, is not so limited. This tool and method can be used advantageously in other environments where internal cutting is involved. For example, it can be employed in horizontal directional drilling and other earth excavating operations. It can be used in virtually any application where conduits or pipes need to be perforated, grooved or severed internally.

Changes can be made in the combination and arrangement of the various parts and elements described herein without departing from the spirit and scope of the invention as defined in the following claims.

CLAIMS

What is claimed is:

1. A cutting tool, comprising:

a body formed by a wall and having a longitudinal axis and comprising a fluid conduit; and

at least one port formed in the body in fluid communication with the fluid conduit, wherein the port is positioned to direct fluid from the fluid conduit through the wall of the body at an angle to the longitudinal axis.

2. The cutting tool of claim 1 wherein the body is elongate.

3. The cutting tool of claim 1 wherein the body is cylindrical.

4. The cutting tool of claim 1 wherein the body has a first end and a second end, wherein the first end is connectable to a rotational drive system and wherein the second end is conical.

5. The cutting tool of claim 4 wherein the first end is provided with threads so as to be connectable to the rotational drive system.

6. The cutting tool of claim 1 wherein the at least one port extends through the wall of the body from the fluid conduit generally perpendicular to the longitudinal axis of the body.

7. The cutting tool of claim 6 wherein the at least one port comprises two ports.

8. The cutting tool of claim 7 wherein the two ports extend axially at 180 degrees from each other.

9. A cutting tool assembly comprising:

a cutting tool comprising:

a body formed by a wall and having a first end, a second end, wherein the body has a longitudinal axis and comprises a fluid conduit; and

at least one port formed in the body in fluid communication with the fluid conduit, wherein the port is positioned to direct fluid from the fluid conduit through the wall of the body at an angle to the longitudinal axis of the body; and

a rotational drive system with a first end and a second end, the first end being connectable to a drive source and the second end connectable to the first end of the cutting tool.

10. The cutting tool assembly of claim 9 wherein the body is elongate.

11. The cutting tool assembly of claim 9 wherein the body is cylindrical.

12. The cutting tool assembly of claim 9 wherein the first end of the cutting tool is threadedly connectable to the second of the rotational drive system.

13. The cutting tool assembly of claim 9 wherein the at least one port extends through the wall of the body from the fluid conduit generally perpendicular to the longitudinal axis of the body.

14. The cutting tool assembly of claim 13 wherein the at least one port comprises two ports.

15. The cutting tool assembly of claim 16 wherein the two ports extend axially at 180 degrees from each other.

16. The cutting tool assembly of claim 9 wherein the rotational drive system is a downhole motor.

17. The cutting tool assembly of claim 16 wherein the downhole motor is Moineau-type positive displacement pump.

18. A method of cutting a tubular member having a lumen defined by a side wall having an inner surface, the method comprising:

directing a jet of fluid from within the lumen of the tubular member at the inner surface of the sidewall in a circumferential motion until the sidewall is at least partially cut.

19. The method of claim 18 wherein the circumferential motion is oscillating.

20. The method of claim 18 wherein the circumferential motion is continuous.

21. The method of claim 18 wherein the circumferential motion is pulsed.

22. The method of claim 18 wherein the circumferential motion is a continuous rotation.

23. The method of claim 18 wherein the fluid is liquid.

24. The method of claim 23 wherein the liquid is water-based.

25. The method of claim 24 wherein the liquid comprises an abrasive agent.

26. The method of claim 25 wherein the abrasive agent is particulate matter.

27. The method of claim 26 wherein the particulate matter is sand.

28. The method of claim 23 wherein the liquid comprises a gelling agent.

29. The method of claim 18 wherein the tubular member to be cut is downhole.

30. The method of claim 29 wherein the circumferential motion of the fluid jet is driven by a downhole motor.

31. The method of claim 30 wherein the fluid is a water-based liquid comprising a gelling agent and particulate abrasive agent.

32. The method of claim 31 wherein the tubular member is well casing.

33. The method of claim 31 wherein the tubular member is production tubing.

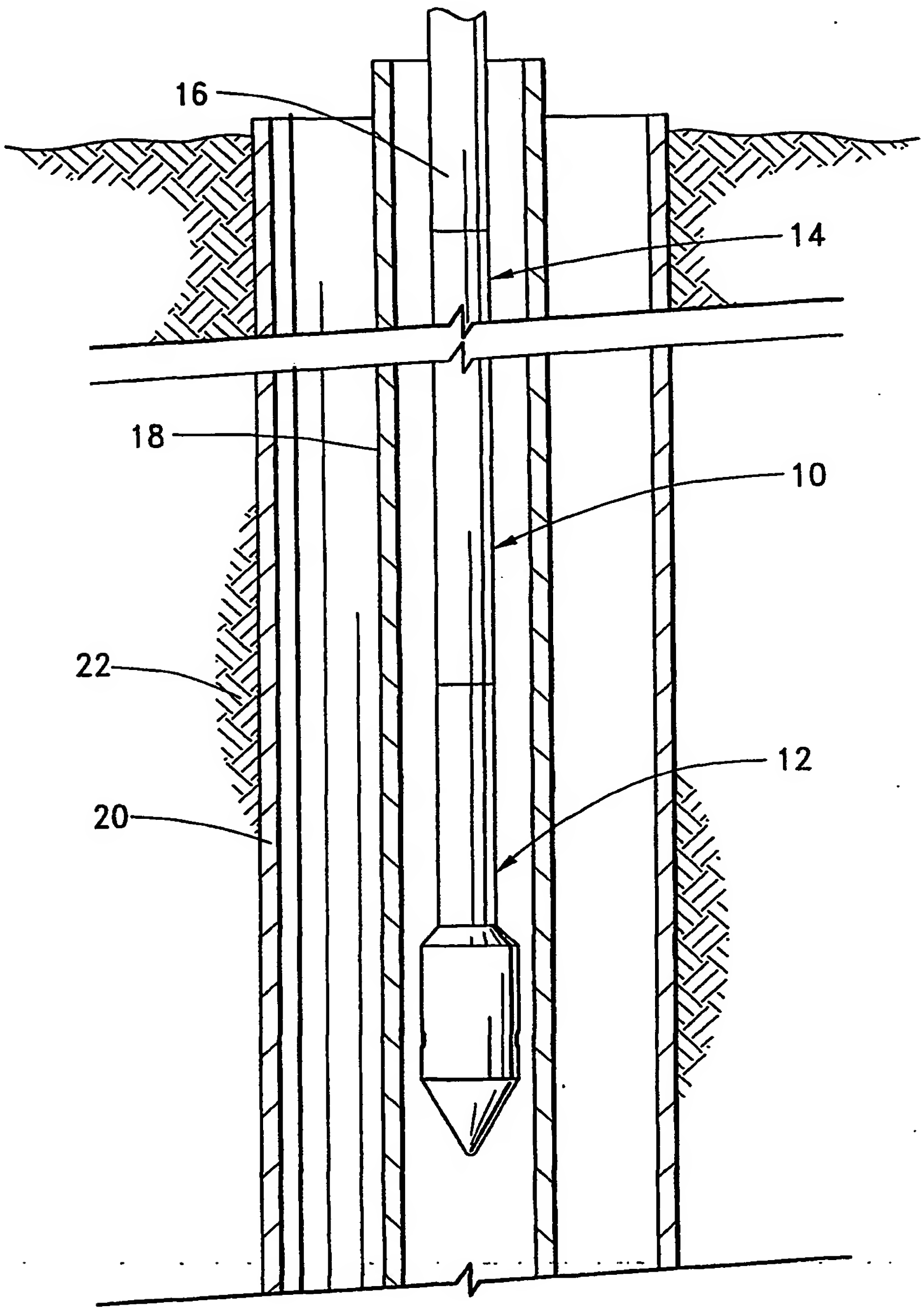

FIG. 1

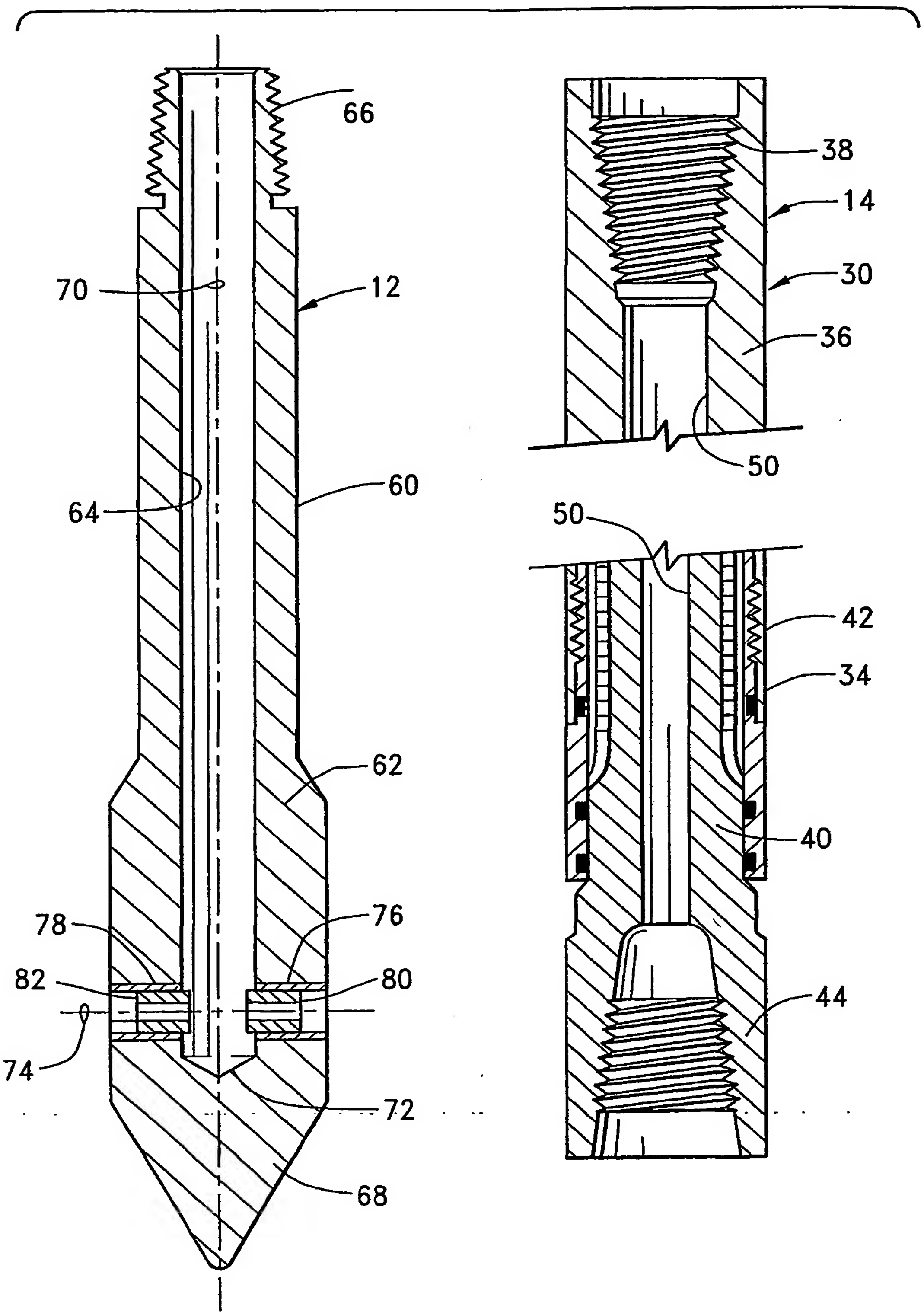

FIG. 2

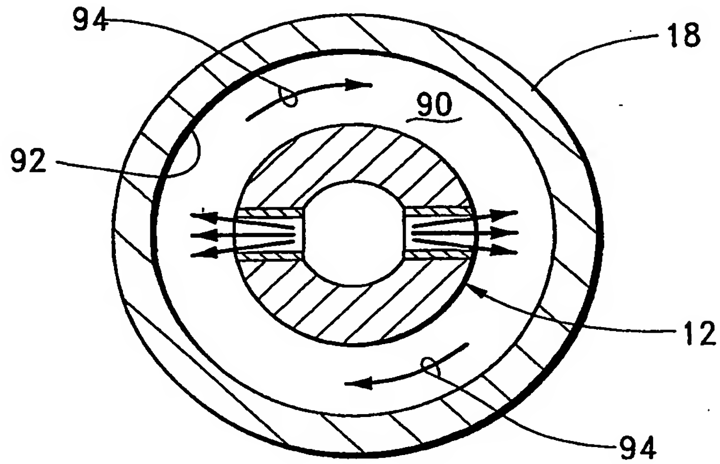

FIG-4

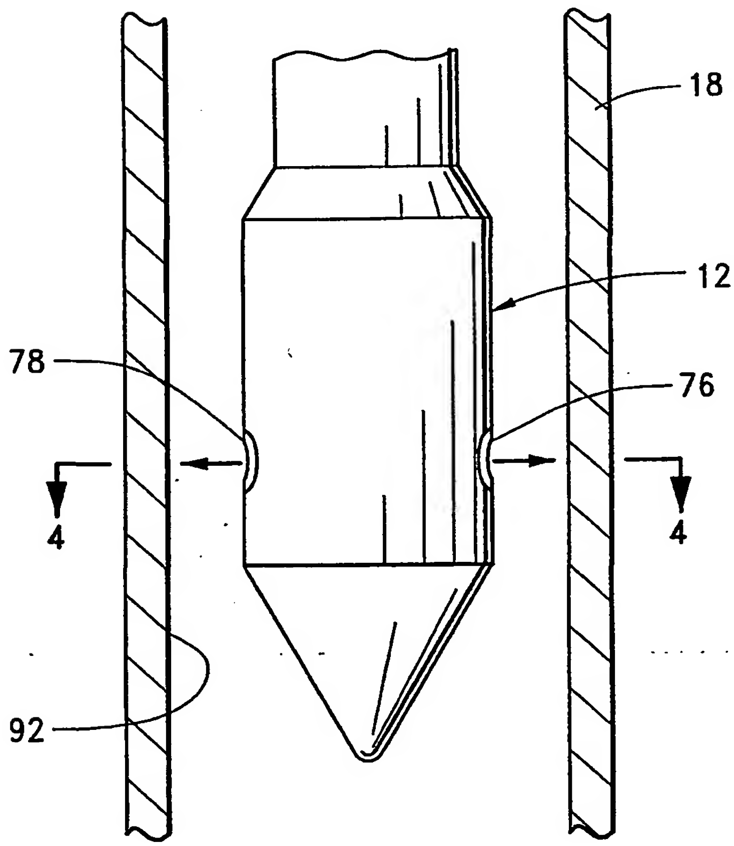

FIG-3